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Marking dependency in non-Markovian stochastic Petri nets

Salvatore Distefano [a,b], Francesco Longo [a,*], Marco Scarpa [a]

[a] Università degli Studi di Messina, Italy
[b] Social and Urban Computing Group, Kazan Federal University, Russia

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ABSTRACT

Marking dependency is a powerful tool that allows different firing time distributions to be associated with a stochastic Petri net transition, depending on the marking. Through this feature, the modeler can easily and compactly represent advanced properties and behaviors of the system. While a semantics and specific solution techniques have been provided for generalized stochastic Petri nets thus covering homogeneous Markovian aspects, in the non-homogeneous/non-Markovian case marking dependency still needs to be investigated. To fill this gap, this paper provides a formalization of marking dependent semantics in non-Markovian stochastic Petri nets (NMSPNs) and a solution technique, based on phase type distributions and Kronecker algebra, able to deal with such a feature allowing both transient and steady-state analyses. To motivate the actual need of marking dependency in NMSPN modeling and to demonstrate the potential of such a feature as well as the validity of the proposed solution technique a case study on a multi-core CPU system with power management facilities is explored.

1. Introduction

Markovian models have been widely used to represent complex systems and quantitatively analyze their non-functional properties. Their success is due to the modeling expressiveness and the effectiveness of the corresponding analysis methods. However, nowadays, information and communication technologies (ICT) aim at automating, enhancing, and improving processes and systems towards higher quality standards, while there are several real phenomena for which the Markovian memoryless assumption does not hold. For example, different activities and events in complex systems (e.g., timeouts, control signals, exceptions) have to be stochastically represented by non-exponentially distributed random variables (r.v.), especially in safety critical and real-time systems. Thus, Markovian models are no longer suitable to meet the required quality standards and in recent years several studies have moved towards more complex stochastic processes (such as those deriving from renewal theory [1], the Levy processes [2], the geometric ones [3], and so on) and more powerful high-level formalisms able to represent complex systems through non-Markovian aspects (e.g., non-Markovian stochastic Petri nets [4], reward and fluid models [5]).

In particular, non-Markovian stochastic Petri nets (NMSPNs), an extension of generalized stochastic Petri nets (GSPNs) with generally distributed events and related memory policies, provide higher accuracy in modeling real systems. Both system modeling [6,7] and evaluation [8,9] techniques have been addressed by literature. With regard to the NMSPN solution, among others, the expansion technique has been proved to be efficient [8], approximating generally distributed events through phase type (PH) distributions [10].

* Corresponding author.
E-mail address: flongo@unime.it (F. Longo).

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